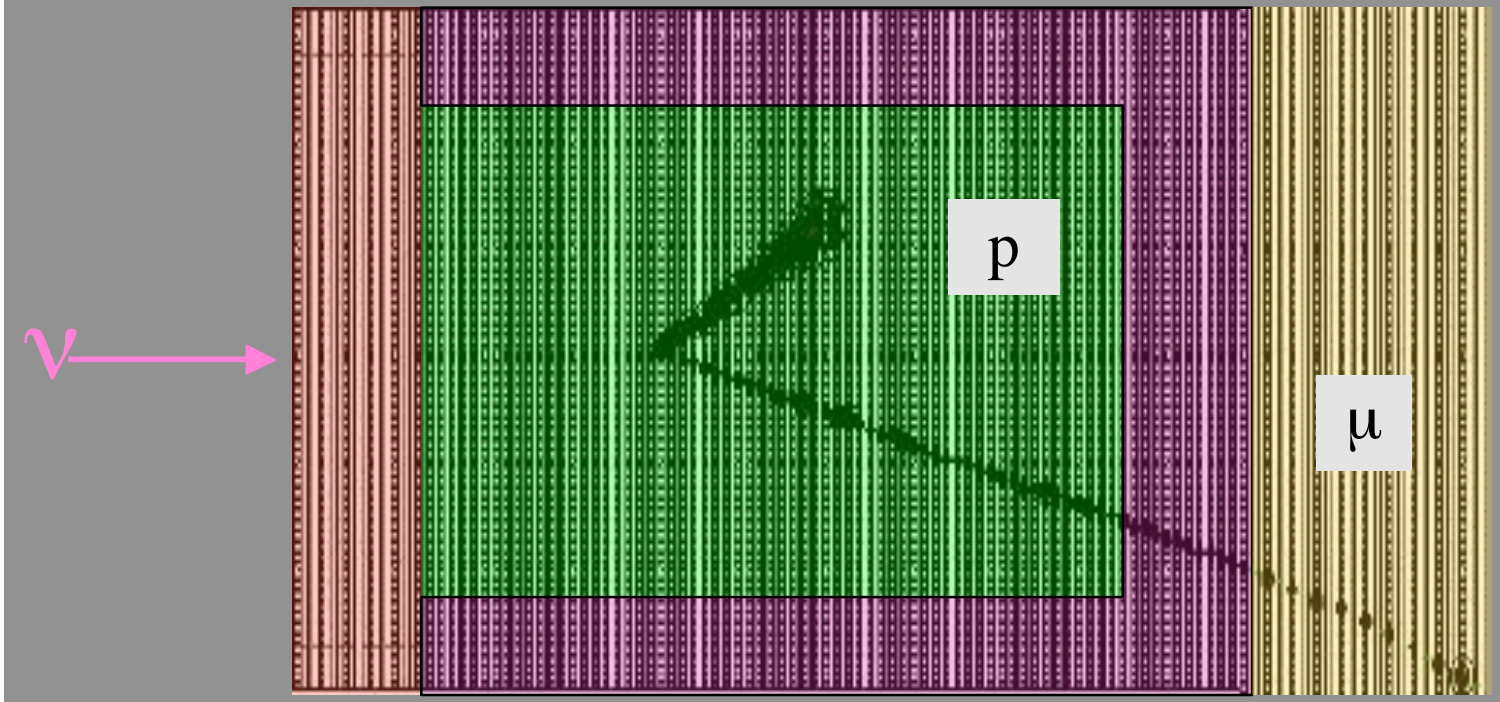
The MINERνA Experiment



Arie Bodek
University of Rochester
Department of Physics and Astronomy
DPF-2006 Honolulu, Hawaii
11:20 AM, Wed. Nov. 1, 2006

University of Rochester

MINERvA Collaboration

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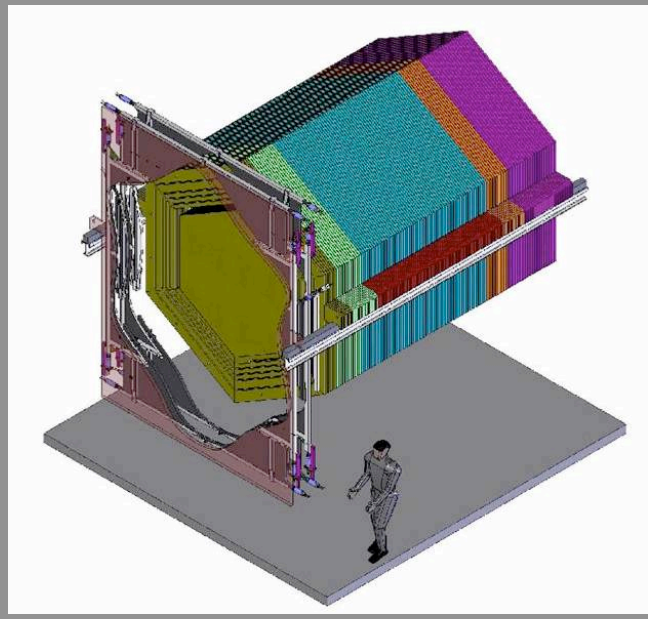
** Co-Spokespersons*
 # Members of Executive Committee

What is MINERνA?

MINERνA proposes to build a precision, highly-segmented ν detector with simple, well-understood technology …



… in the NuMI beam just upstream of MINOS.

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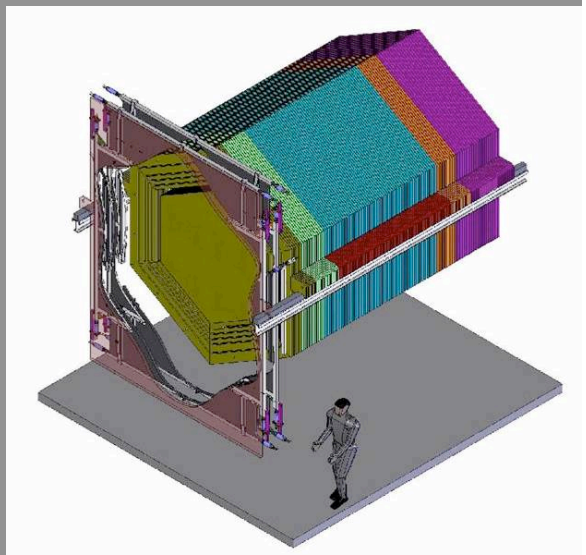


- Active core is segmented solid scintillator
  - ♣ tracking (incl. low momentum protons)
  - ♣ particle identification
  - ♣ few ns timing (track direction, identify stopped $K^{\pm}$)
- Surrounded by electromagnetic and then hadronic calorimeters
  - ♣ Photon (π^{o}) and hadron ($\pi^{\pm}$) energy measurement
- C, Fe and Pb nuclear targets upstream of solid scintillator
- MINOS near detector as high energy μ spectrometer downstream

Also: recent NSF MRI award for nuclear targets and calibration system

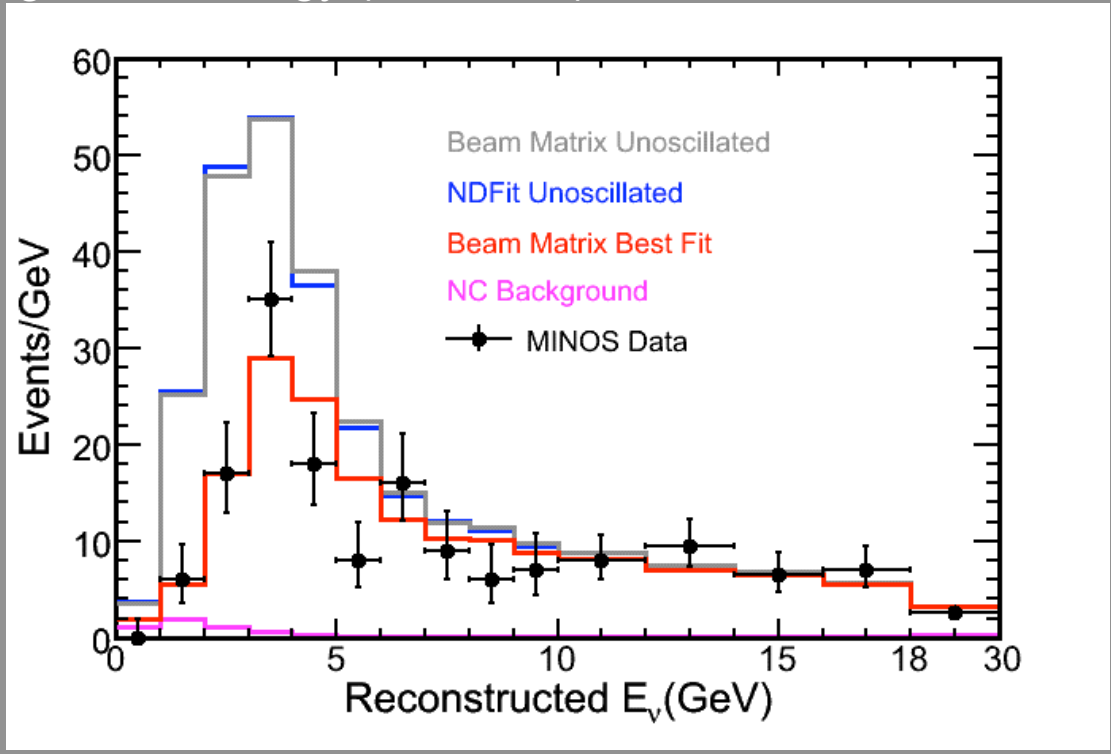
Motivation for MINERνA

Entering a period of precision neutrino oscillation measurements …

Got E_ν??

- Precision understanding of low energy (Few GeV) neutrino cross sections
- Models
- Nuclear effects
- Final state details

Recent results from MINOS

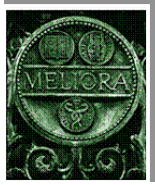


hep-ex/0607088

Motivation for MINERνA

The recent APS Multidivisional Neutrino Study Report predicated its recommendations on a set of assumptions about current and future programs including: support for current experiments, international cooperation, underground facilities, R&D on detectors and accelerators, and

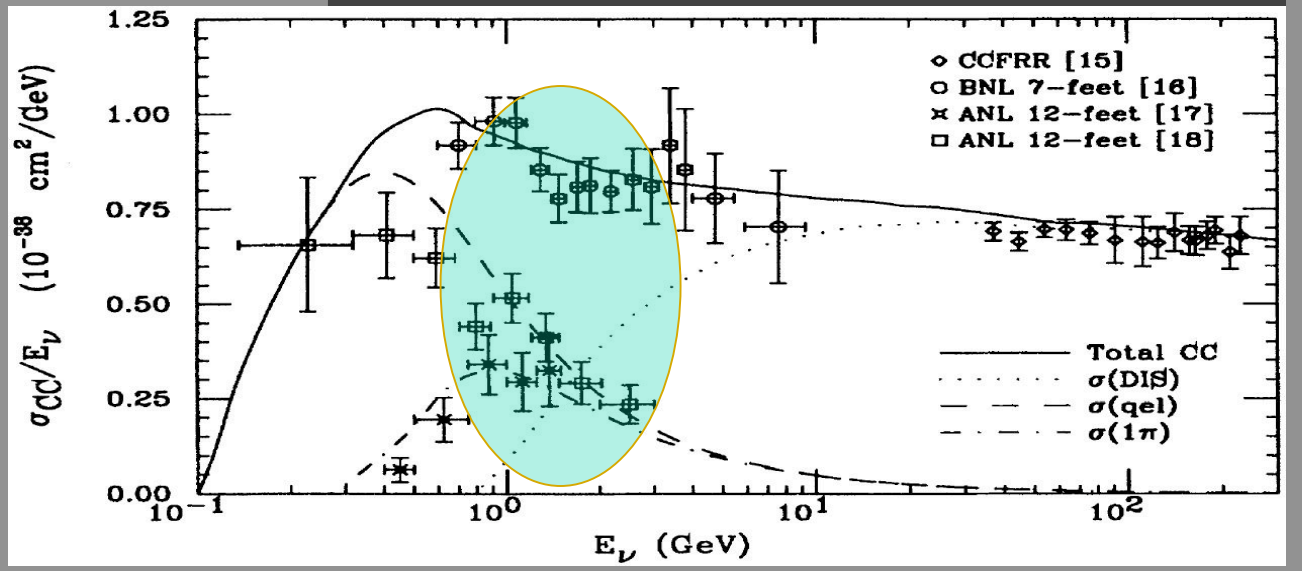
determination of the neutrino reaction and production cross sections required for a precise understanding of neutrino-oscillation physics and the neutrino astronomy of astrophysical and cosmological sources. Our broad and exacting program of neutrino physics is built upon precise knowledge of how neutrinos interact with matter.



MINERνA Physics: Low Energy Neutrino Scattering

We will be making precision measurements of low energy neutrino cross sections:

Lipari, Lusignoli and Sartogo, PRL 74, 4384 (1995)

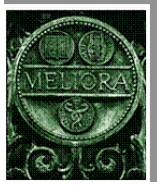


Contributions to total cross section: $\sigma_{TOT} = \sigma_{QE} + \sigma_{RES} + \sigma_{DIS}$

σ_{QE}: Quasi-elastic -> $\nu(\overline{\nu})\, n(p) \rightarrow \mu^-(\mu^+)\, p(n)$

σ_{RES}: Resonance -> $\nu N \rightarrow \mu N^*$ Inelastic, Low-multiplicity final states

σ_{DIS}: Deep Inelastic Scattering -> $\nu N \rightarrow \mu X$ Inelastic, High-multiplicity final states



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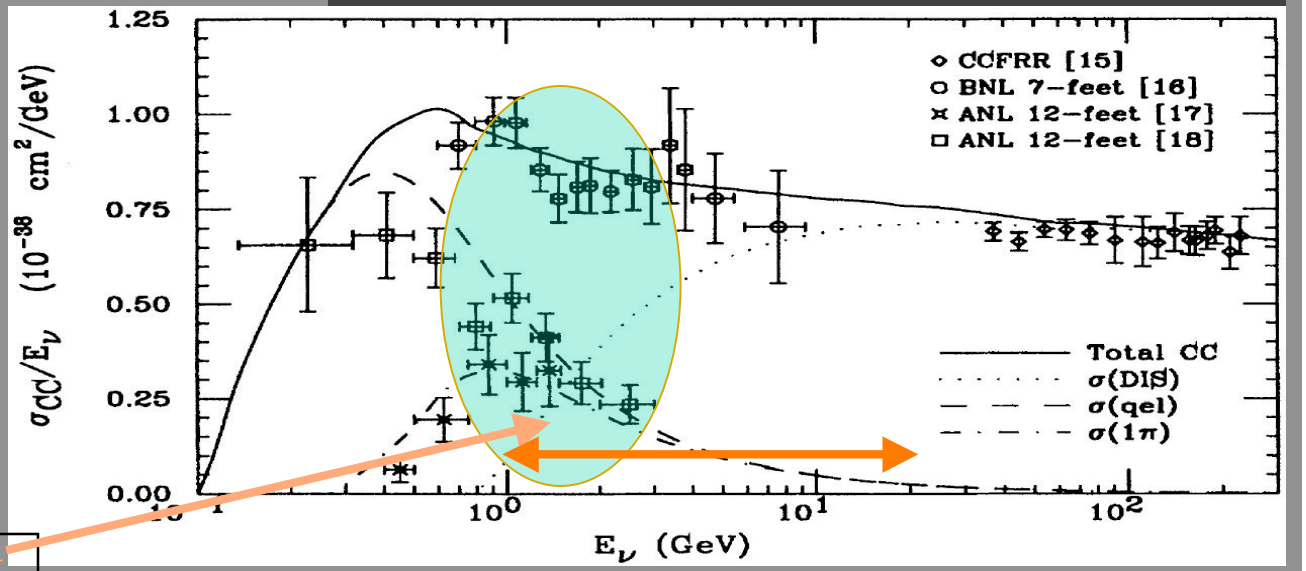
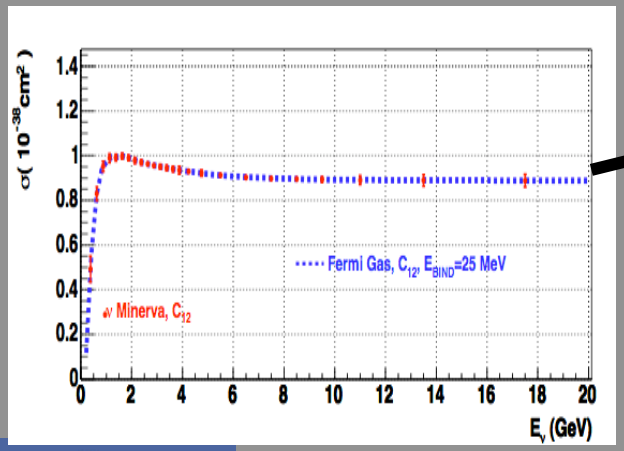
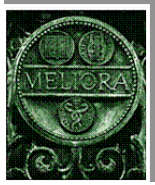


NuMI flux range 1-20 GeV



Estimated Cross section uncertainties

Process		Current	After MINERνA
QE	~	20%	5%
Res	~	40%	5/10%(CC/NC)
DIS	~	20%	5%
Coh	~	100%	20%



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CVC Partnership: NP (e-A Vector - Jlab JUPITER) HEP (vA axial+vector ; Fermilab MINERvA)

K. McFarland-Rochester, J. Morfin, FNAL

MINERvA HEP Spokespersons

significant NP participation in MINERvA because of overlap of physics with Jefferson Lab community

Neutrino Physics Comes to JLab

The inner workings of the sun, the mysteries of dark matter and dark energy and the structure of the early universe all may be unlocked by one cosmic key: neutrinos. Now, new research carried out in Jefferson Lab's experimental Hall C may help provide insight into neutrinos, the force that governs their behavior and, surprisingly, the structure of the nucleus of the atom.

Fermilab Today

Nuclear Option: MINERvA Attracts Nuclear Physicists

This is the fourth article in a series on the MINERvA neutrino experiment.

"MINERvA offers us the possibility of making a bridge in our understanding between the longer distance-scale properties of the nuclear force--responsible for the properties of nuclei--and the very short-distance scales explored in particle physics," says Ransome. "And this intermediate distance scale is of great interest to both communities."

University of Rochester

Arie Bodek
Oct 2

JLab program e-A (JUPITER)Spokespersons

A. Bodek - Rochester HEP

Cynthia Keppel - Hampton/Jlab - NP

Data for neutrino cross-section modeling

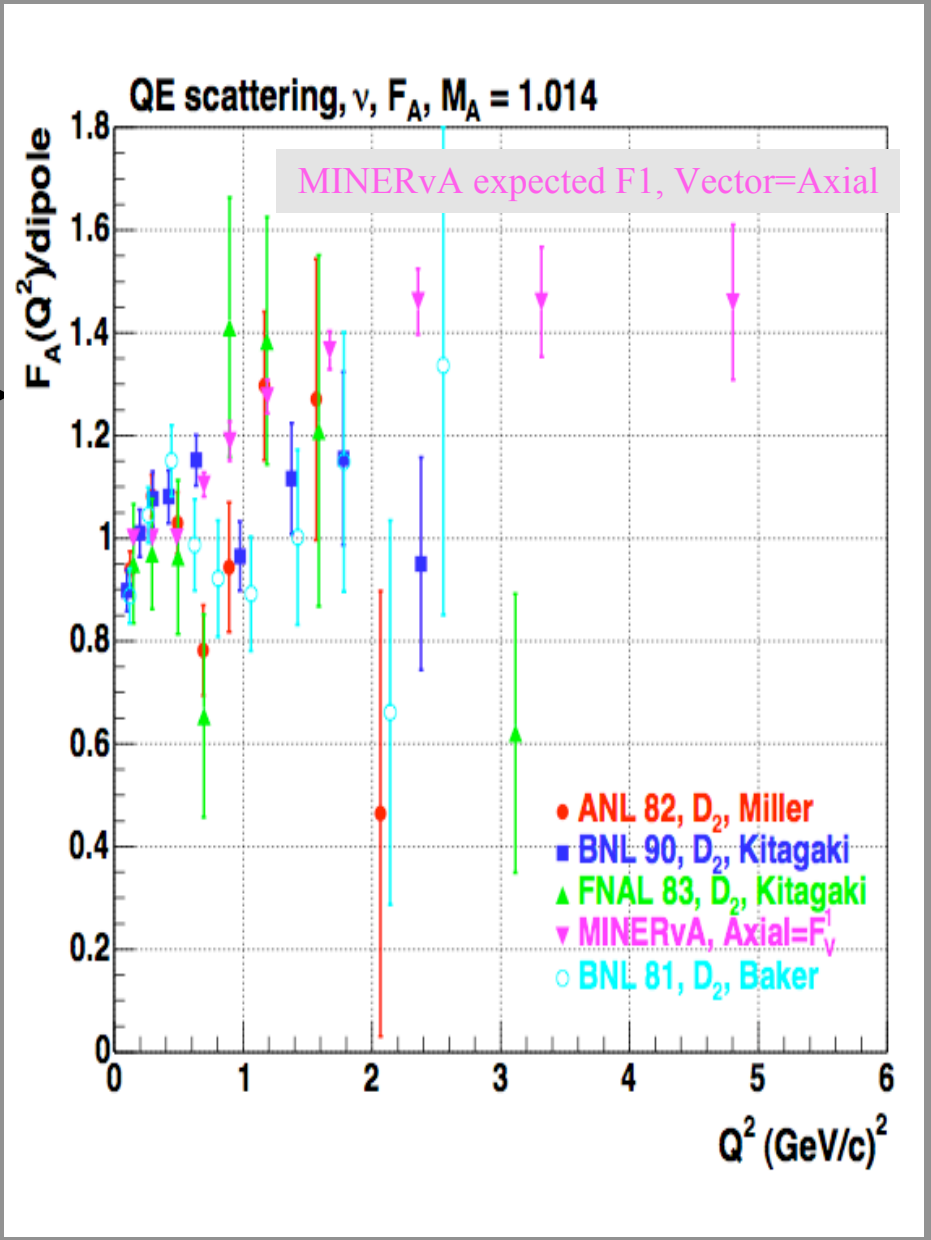
already run one dedicated experiment (Jlab E04-001)- Hall B inclusive

Active program of data mining with neutrinos in mind- Hall C, exclusive

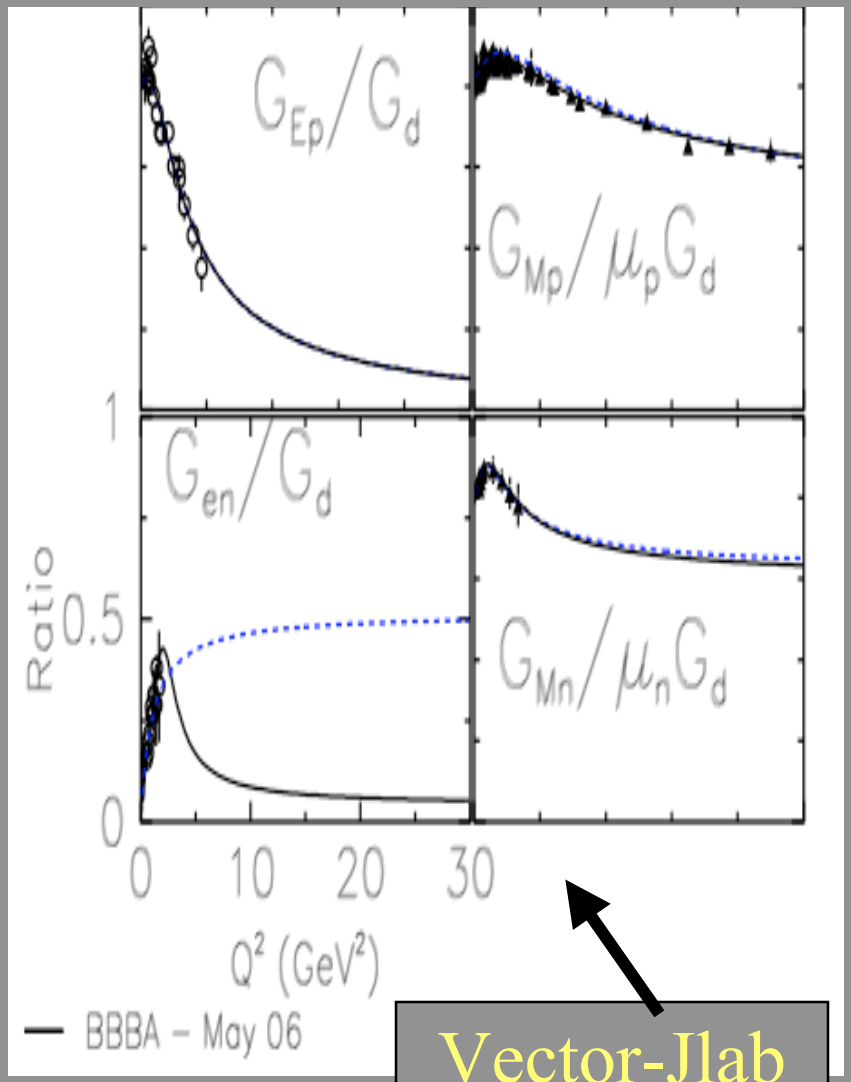
Motivation for MINERνA

Cross sections interesting in their own right

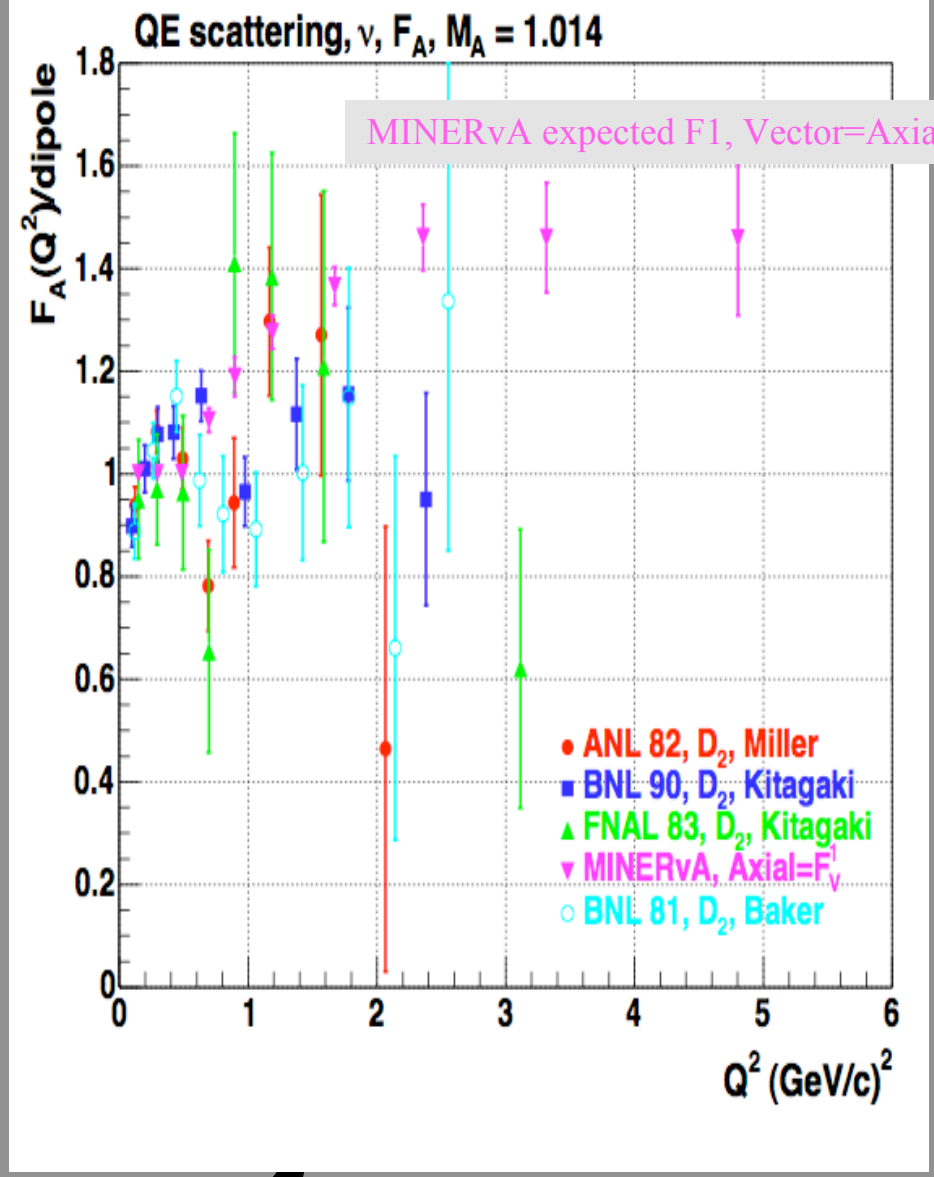
- Determination of axial form factor $F_A(Q^2)$
- Duality in neutrino interactions
  - Do the averaged structure functions in the resonance region agree with extrapolated DIS structure functions?
- Nuclear effects
- Coherent pion production
- DIS and resonance structure functions, high-x PDFs
- Strangeness and charm production
- Resonance production



Motivation for MINERνA



Vector-Jlab



Axial -MINERvA

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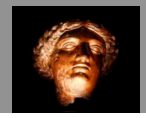
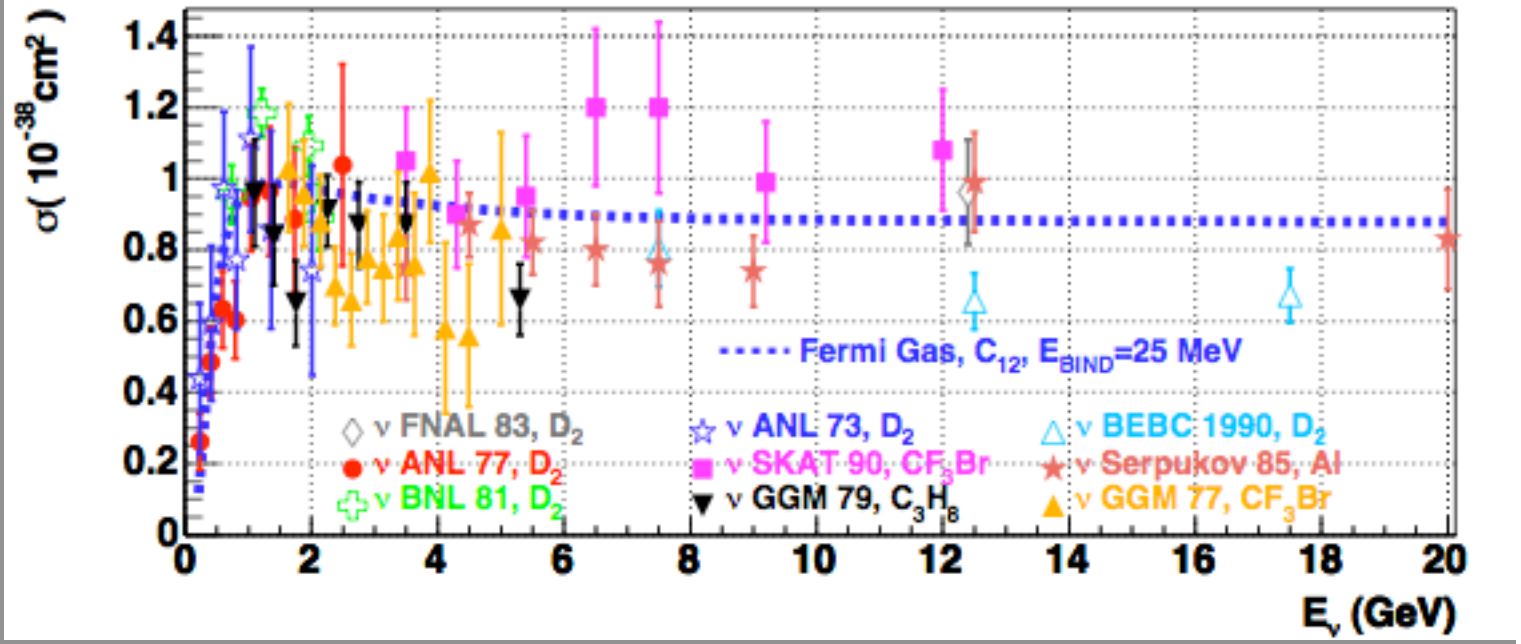
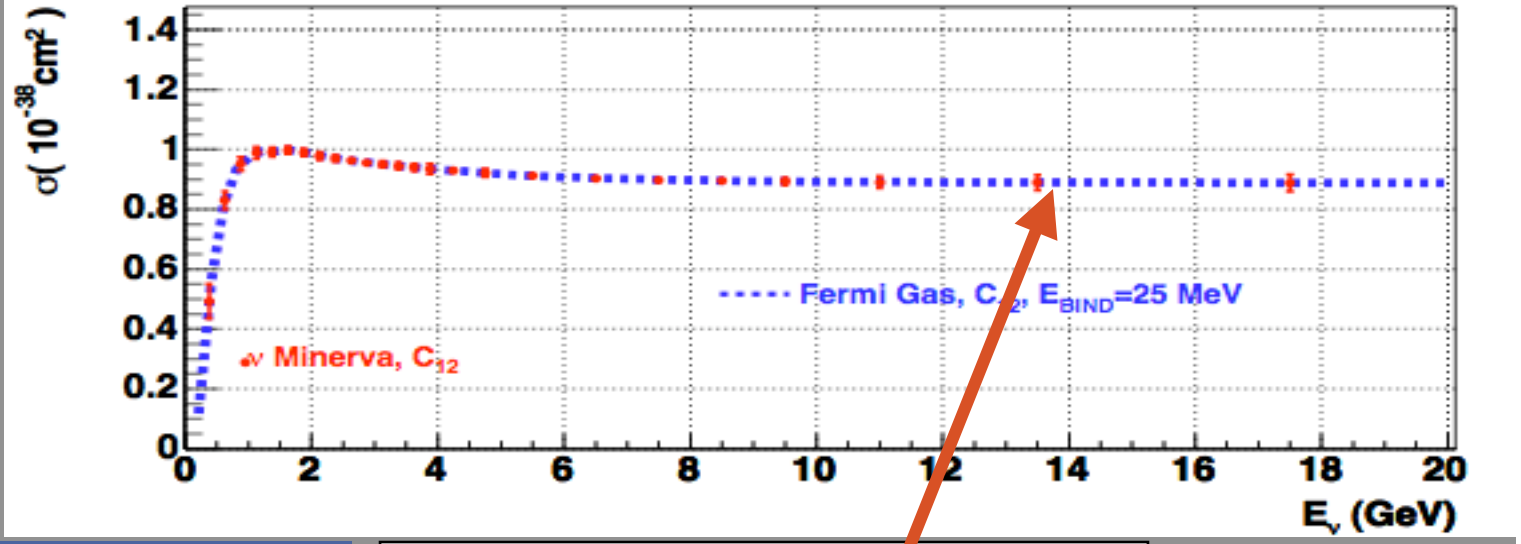
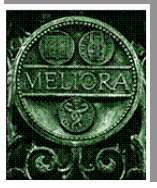


Motivation for MINERνA







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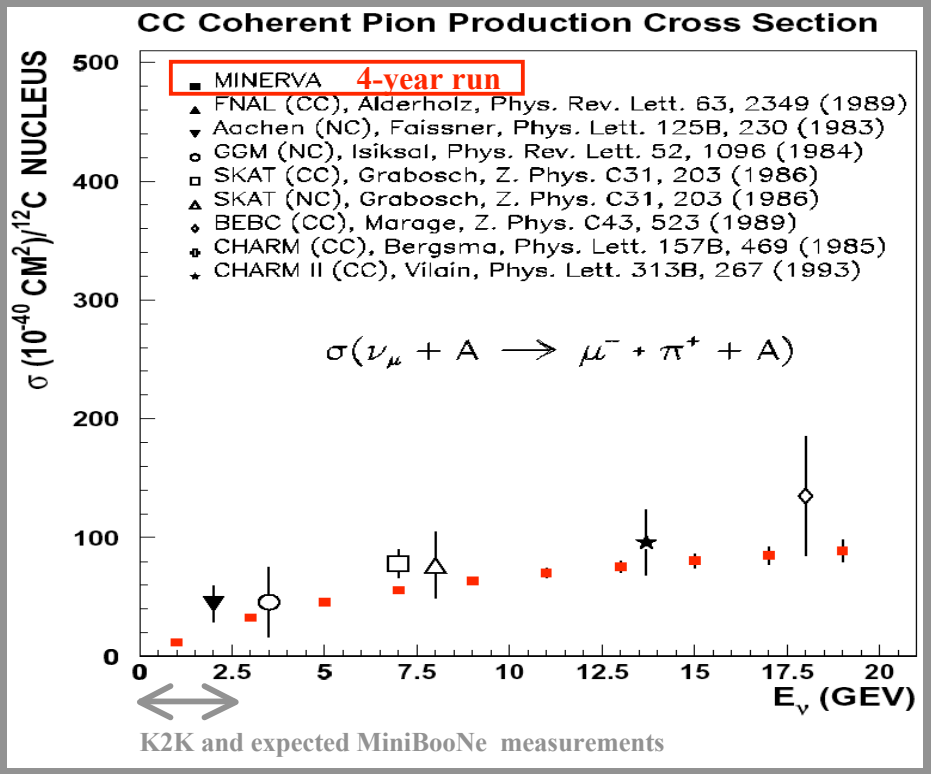
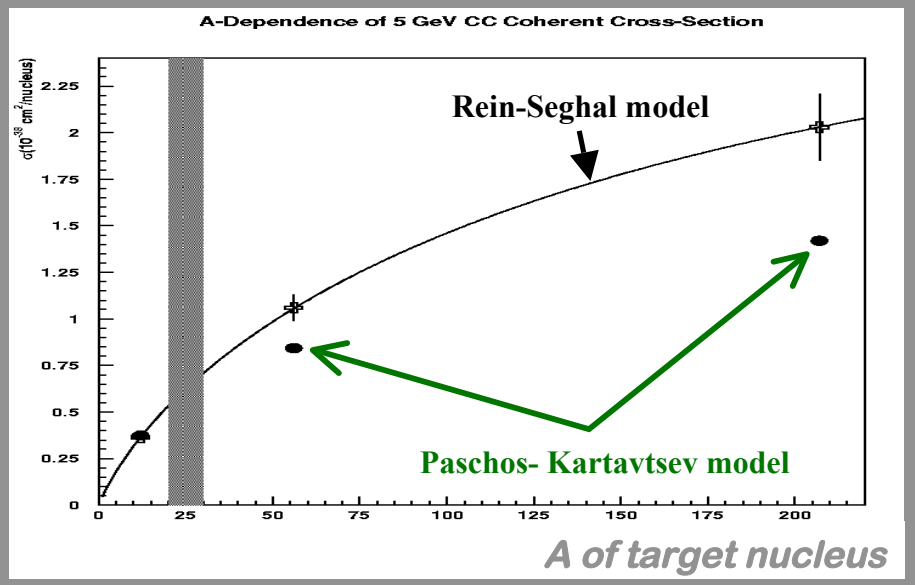
MINERνA Quasielastic

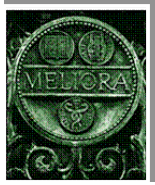
Coherent Pion Production





MINERνA's nuclear targets allow the first measurement of the A-dependence of σ_{coh} across a wide A range \ Distinguish between models

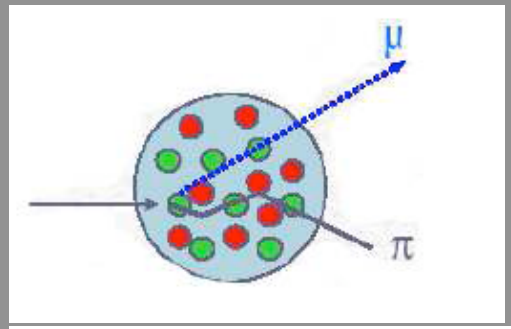
- Provides a test of the understanding of the weak interaction
  - Cross section can be calculated in various models
- Neutral pion production is a significant background for neutrino oscillations
  - π^0 shower easily confused with an electron shower: $\nu_\mu \cdot \nu_e n \cdot e^- p$, $\nu_\mu A \cdot \nu_\mu \pi^0 A$



MINERνA and Oscillations
Example: Nuclear Effects on MINOS

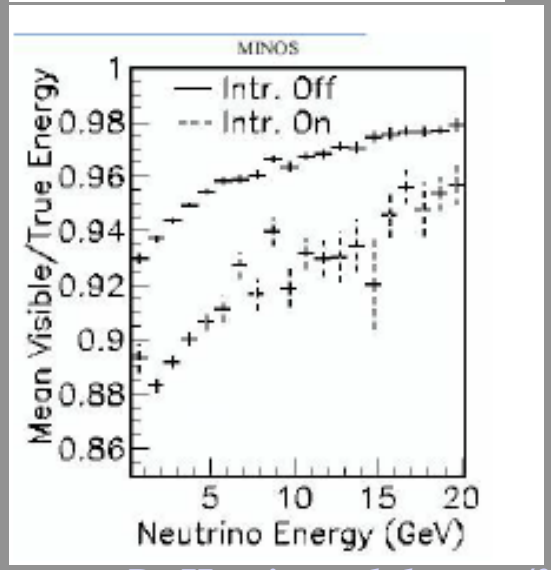
Final State Interactions

- ♣ Intranuclear rescattering
- ♣ Energy loss and/or absorption
- ♣ Change in direction



MINOS Iron Calorimeter -
Nuclear effects among
the largest systematics

Changes measured visible energy
Spectrum: Translate to shift in Far/Near
'dip' location -> Δm^2



D. Harris et al. hep-ex/0410005

MINERνA : measurements with high-A targets and high-statistics

MINERνA and Oscillations
Example: Nuclear Effects on MINOS

Final State Interactions

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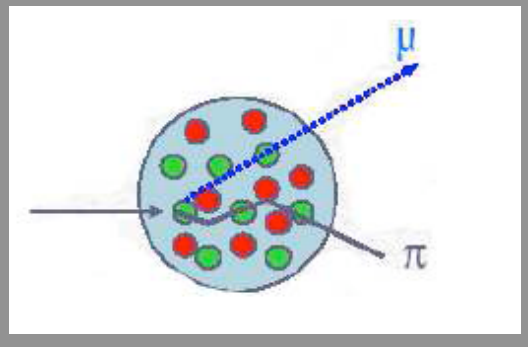
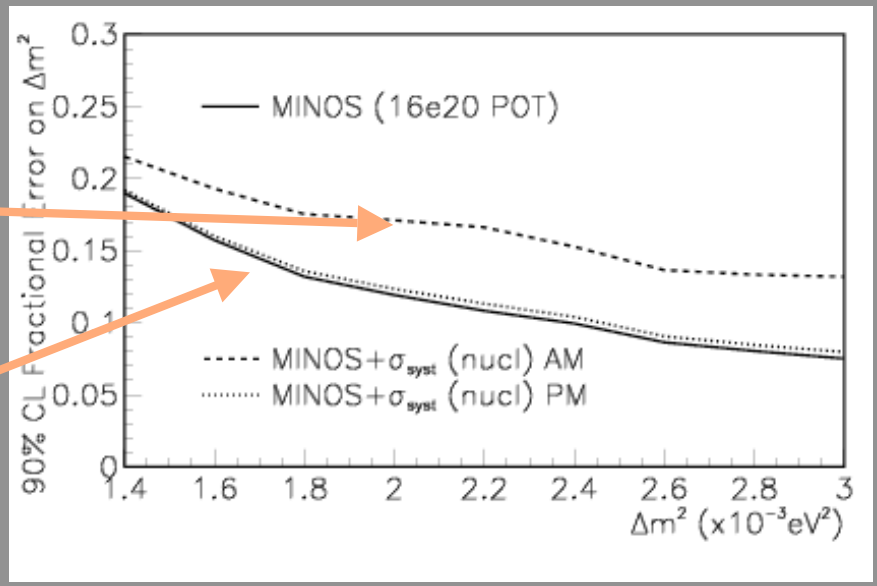


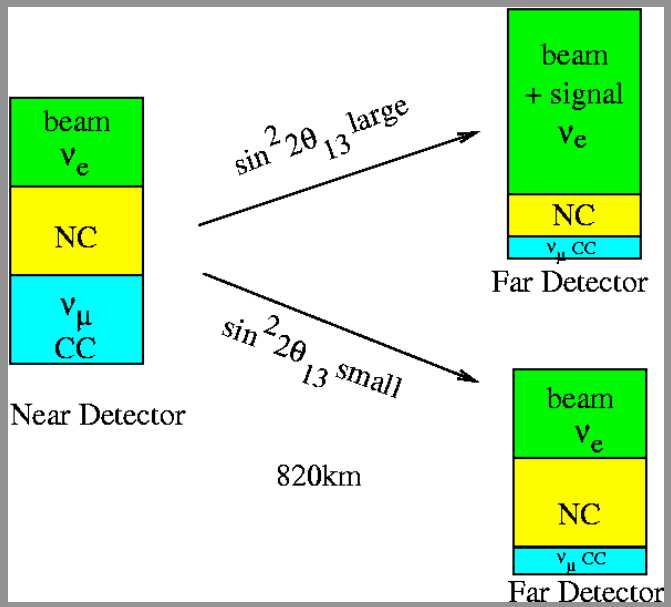
Before MINERνA
$\sigma_{stat} \sim \sigma_{syst}$ (rescattering only)

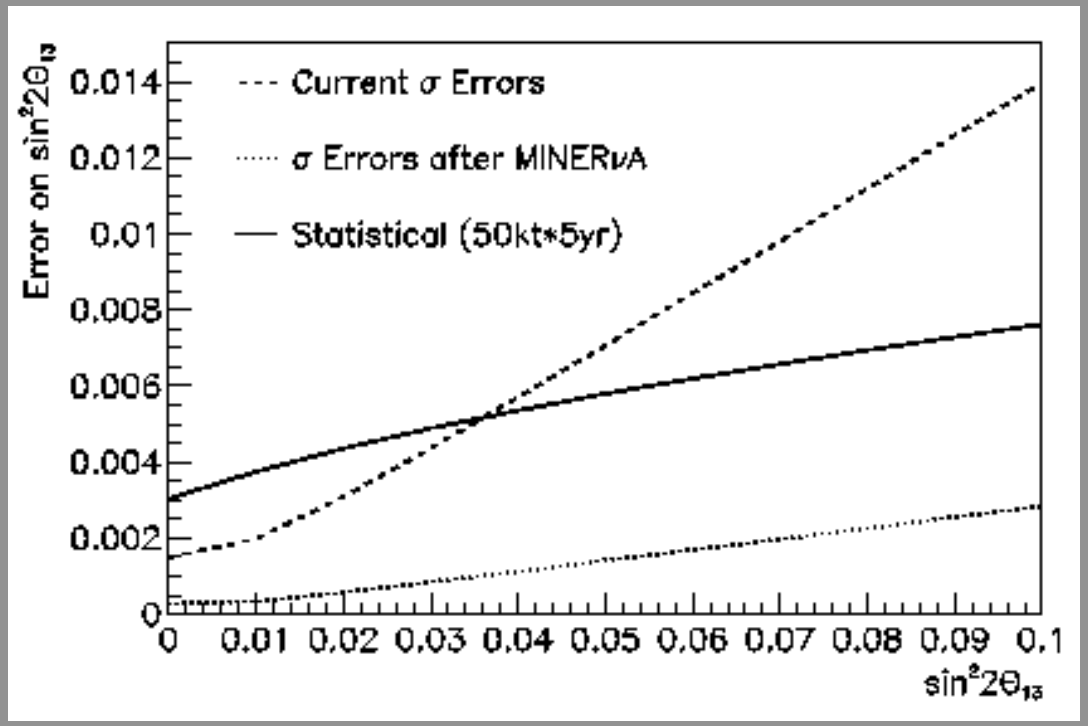
After MINERνA:
$\sigma_{stat} >> \sigma_{syst}$ (rescattering only)



MINERνA: measurements with high-A targets and high-statistics

How NOνA can use MINERνA Measurements

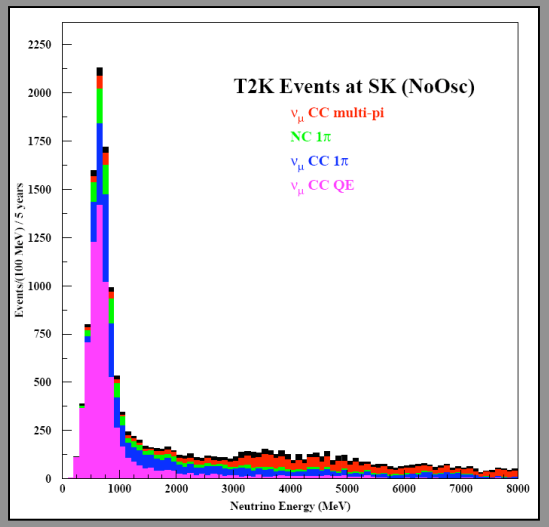


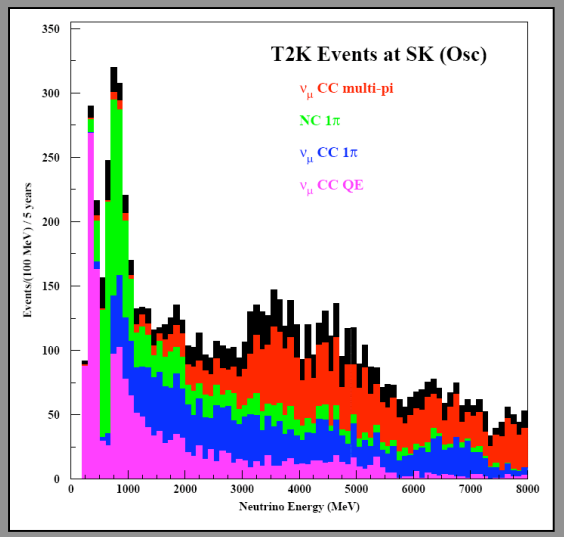


Process	QE	RES	COH	DIS
δσ/σ NOW (CC,NC)	20%	40%	100%	20%
δσ/σ after MINERνA (CC/NC)	5%/na	5%/10%	5%/20%	5%/10%

Study is for old NOνA design, but results expected to be qualitatively similar with totally active (TASD) design

How can T2K use MINERvA measurements





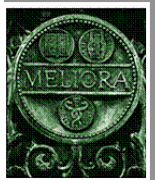
D. Harris et al. hep-ex/0410005

Note that as in NOvA, T2K's near detector will be a very different mix of events than the far detector.

To make accurate prediction, need

- ♣ 1 - 4 GeV neutrino cross sections
- ♣ Energy Dependence of cross sections

MINERvA can provide these with NuMI beamline Low Energy running!



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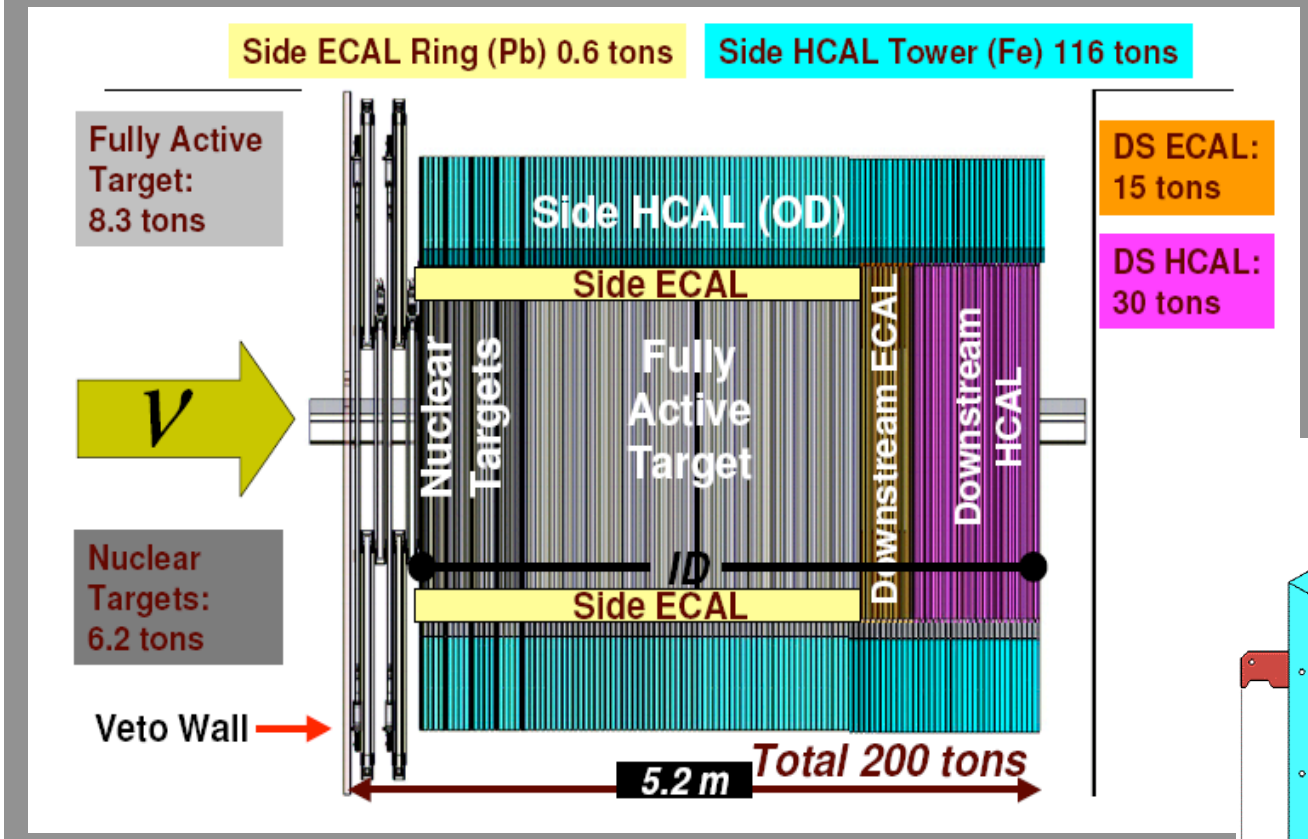
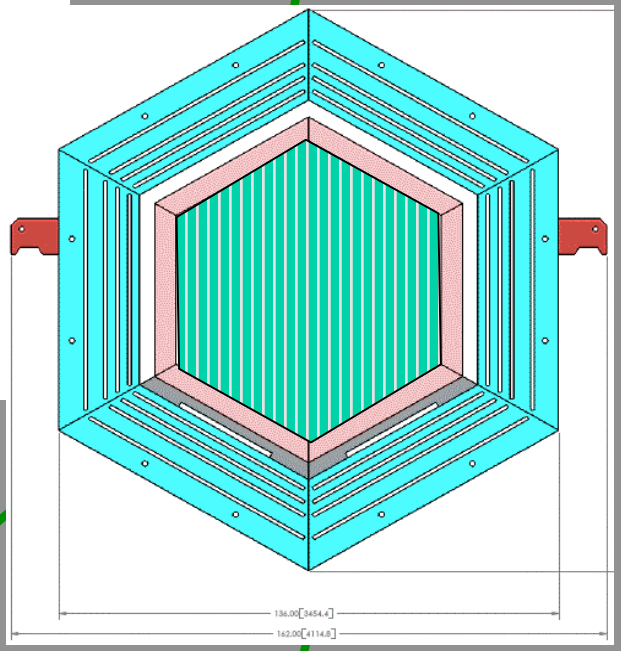
MINERνA Detector



Side View

Outer Detector (OD) Layers of iron/scintillator for hadron calorimetry:

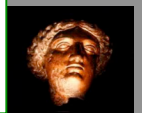
6 Towers



Front View

Inner Detector Hexagon
– X, U, V planes for stereo view

Lead sheets for EM calorimetry

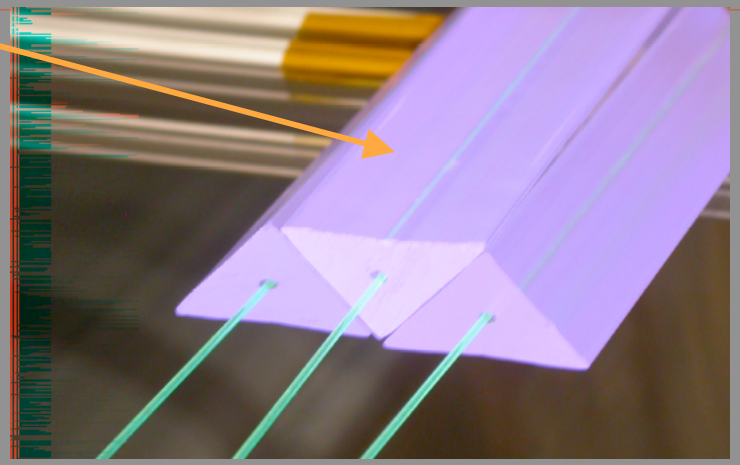


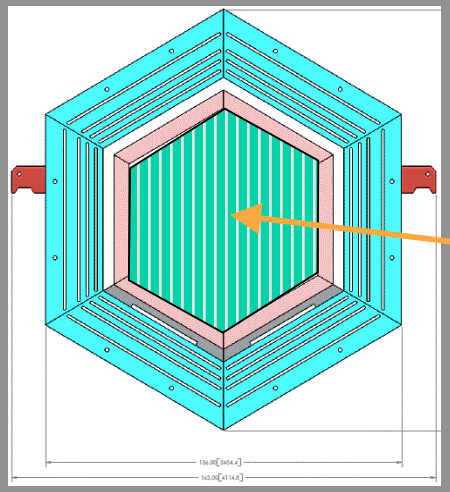
MINERvA Detector

Detector Channel Count:

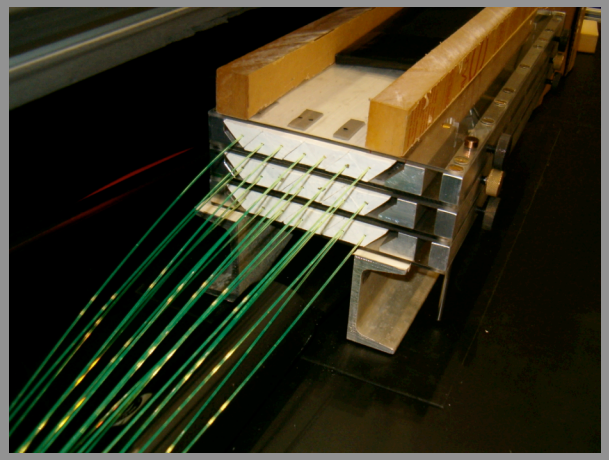
- **31,000 channels**
  - 80% in inner hexagon
  - 20% in Outer detector
- **503 M-64 PMTs** - 64 channels
- **128 pieces of scintillator per Inner Detector plane**

Active elements are 1.7x3.3 cm triangular bars of extruded scintillator with embedded 1.2 mm WLS fibers





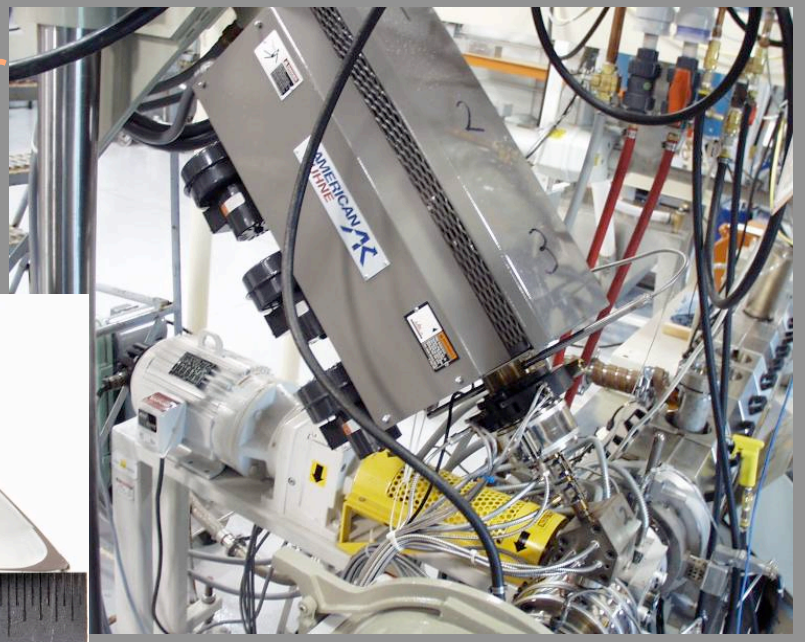
Inner detector is totally active scintillator strip detector. Alternating planes rotated by 60 degrees to make 3 views (XUXV)



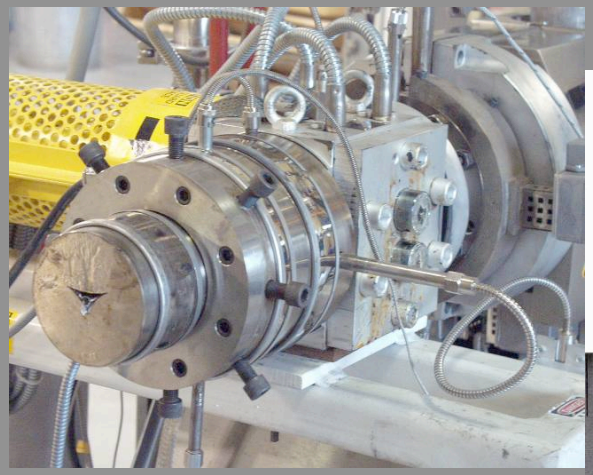
MINERνA: R&D / prototyping

- Inner detector scintillator triangles
  - ♣Demonstrated feasibility of meeting mechanical specs
  - ♣Provide scintillator for light yield measurements

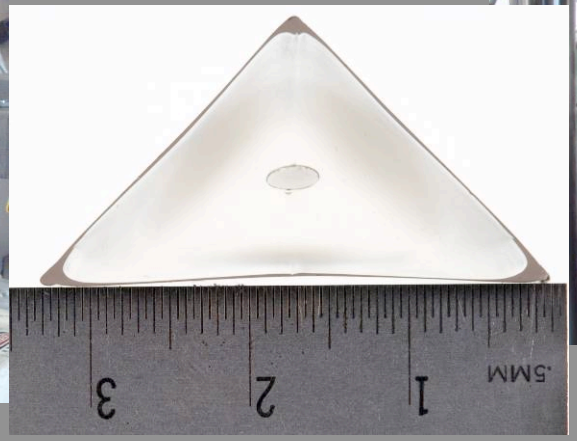
Co-Extruder



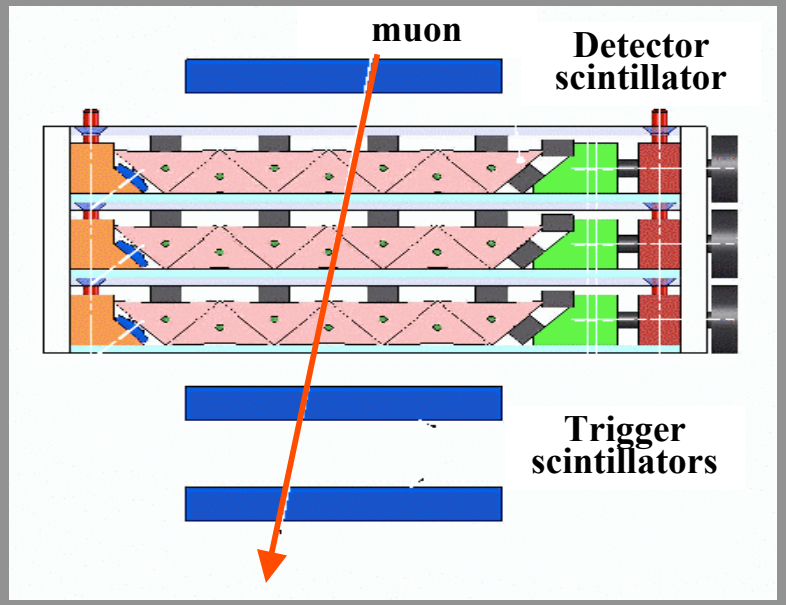
Triangle Die



X-section of scintillator

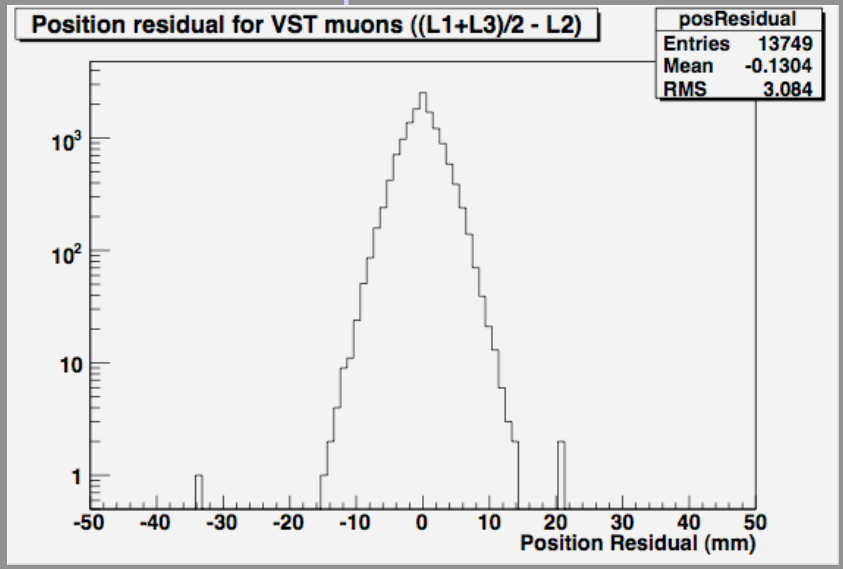


MINERνA: R&D / Prototyping / expected performance



- Vertical slice test
  - 3-layer, 21 scintillator prototype (including MINERνA electronics)
  - Measured 21 pe/MIP for each layer
  - Light yield important for tracking
  - Min-I track position resolution

Howard Budd
Jesse Chvojka



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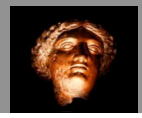
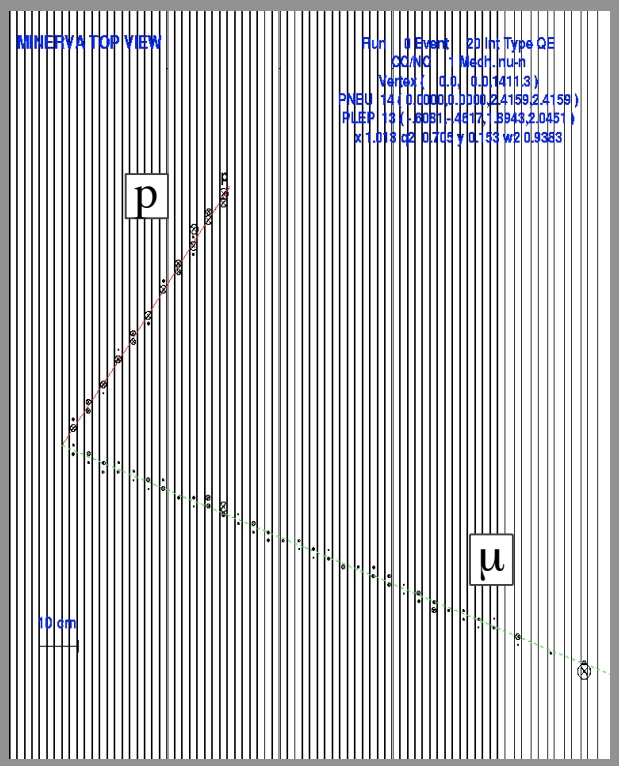
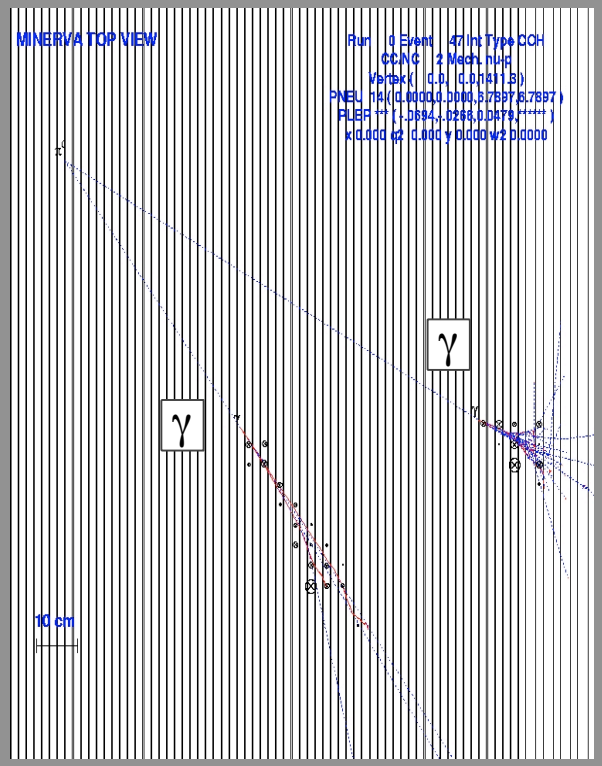
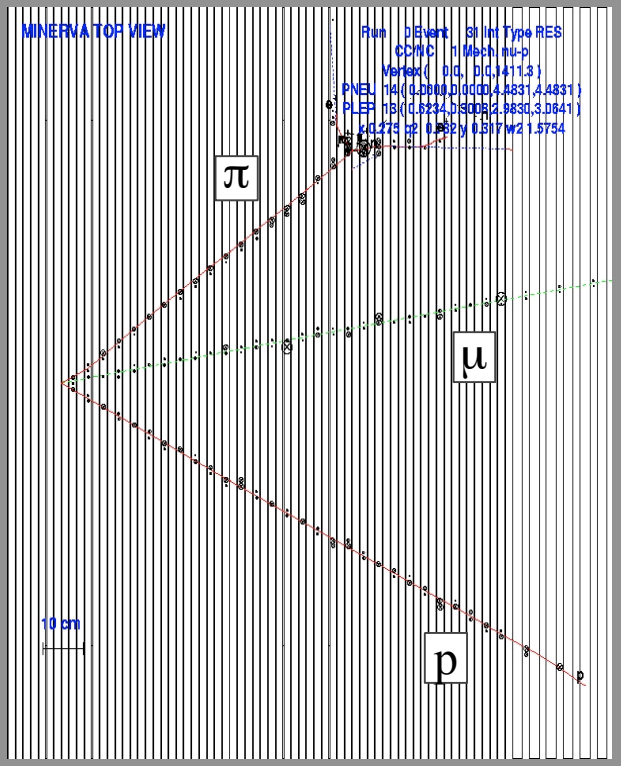


MINERνA Events







Quasielastic event

$\nu_\mu\, n \rightarrow \mu^-\, p$

Neutral Current π^0

$\nu_\mu\, A \rightarrow \nu_\mu A\, \pi^0$

Resonance production

$\nu_\mu\, p \rightarrow \mu^-\, \Delta^{++} \rightarrow \mu^-\, p\, \pi^+$

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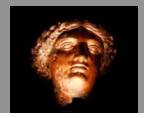
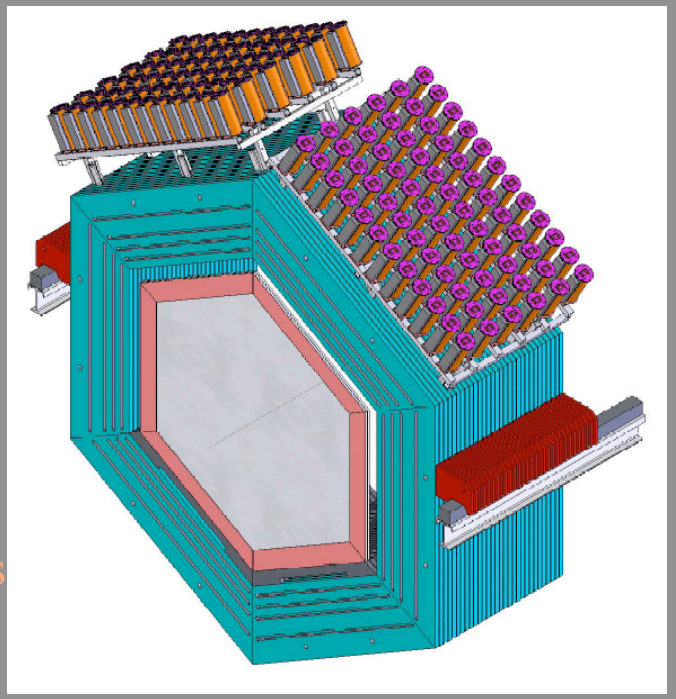


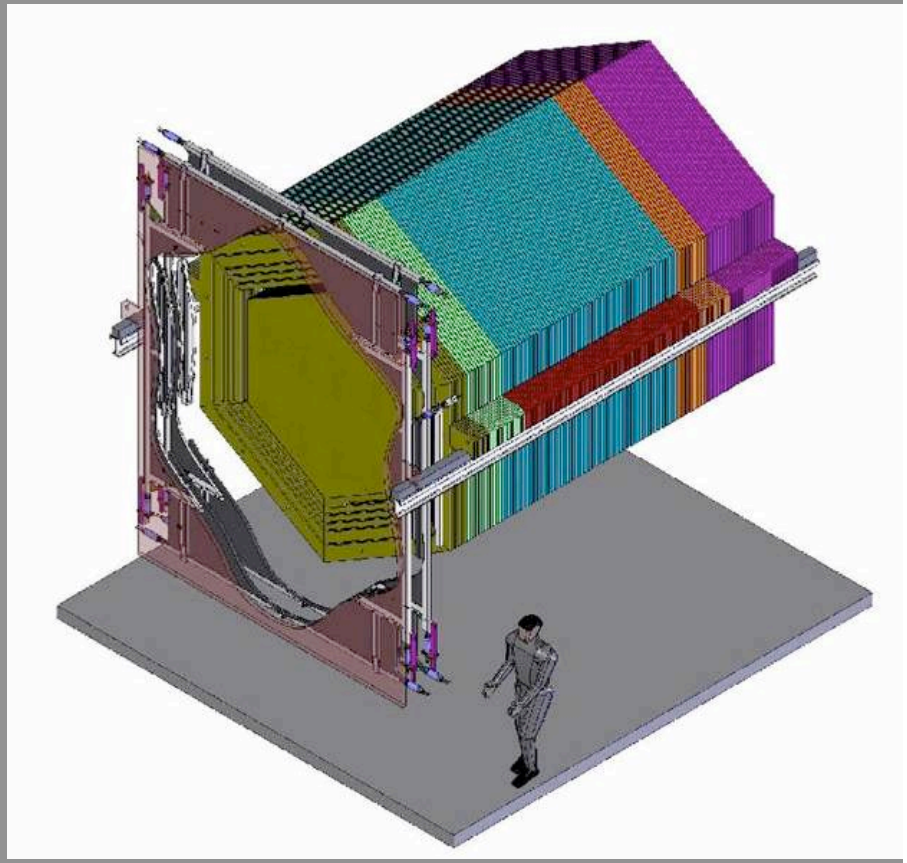
MINERνA: Cost and expected schedule

- Modest cost detector
- 2006 Continue R&D with Vertical Slice Test
- 2007 Multi-plane Tracking Prototype:
  - Roughly 20% of the full detector
  - Full EM Pb Calorimeter, no hadron Calorimeter
  - Tests to be performed
    - Construction and QC procedures
    - Scintillator spacing uniformity
    - Plane uniformity across many planes
    - Planes stacked as close as physics dictates?
    - How to replace PMT Boxes /front end boards
- 2008 Begin running with tracking prototype
  and Complete construction
- 2009 Cosmic Ray and neutrino data!



Summary

- MINERvA
  - Opportunity for precision neutrino interaction measurements
  - Wide range of neutrino energies
  - Several different nuclear targets allows study of nuclear effects
  - Important input to current and future oscillation measurements
- Hoping for data in 2009!



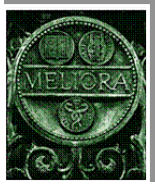
Backup Slides

Abstract

MINERvA is a dedicated neutrino cross-section experiment planned

for the near detector hall of the NuMI neutrino beam at Fermilab.

The detector design and physics capabilities of the experiment are summarized.



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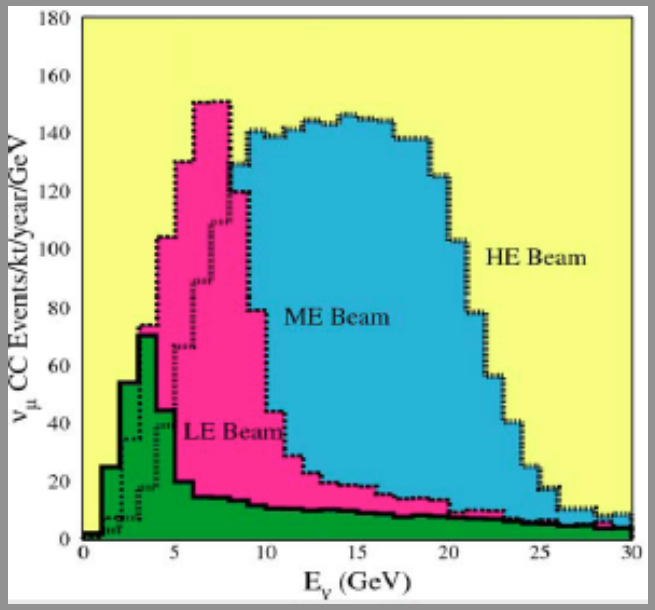
MINERνA Event Rates

NUMI Beams

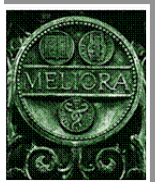


- Fiducial Volume
  - ~3 t CH
  - ~0.6 t C
  - ~0.5 t Fe
  - ~0.5 t Pb
- Expected CC event samples
  - 8.6 M ν events in CH
  - 0.4 M ν events in C
  - 2.0 M ν events in Fe
  - 2.5 M ν events in Pb

Assumes 16.0×10^{20} POT in LE and ME NuMI beam configurations over 4 years

Main CC Physics Topics (Statistics in CH)

Quasi-elastic	0.8 M events
Resonance Production	1.6 M total
Transition: Resonance to DIS	2 M events
DIS, Structure Funcs. and high-x PDFs	4.1 M DIS events
Coherent Pion Production	85 K CC / 37 K NC
Strange and Charm Particle Production	> 230 K fully reconstructed



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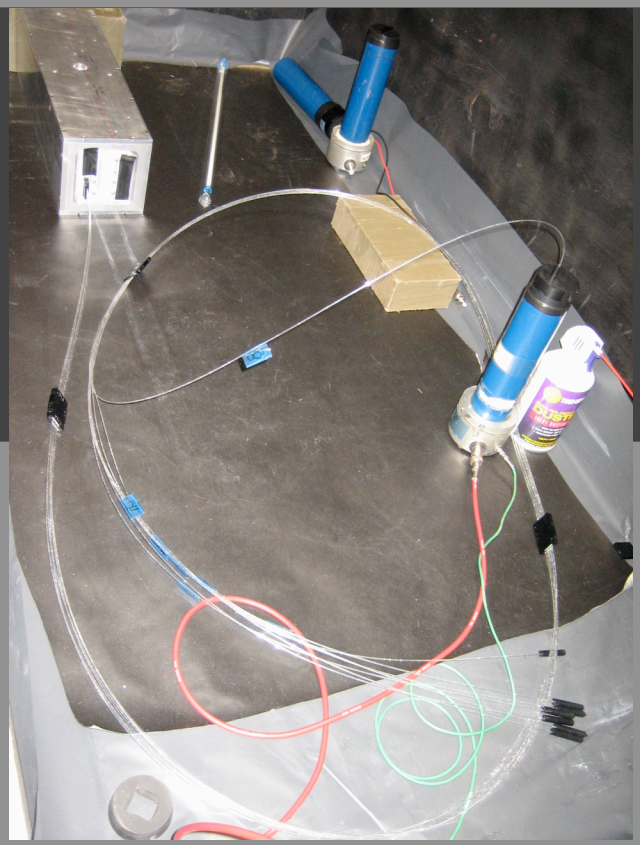
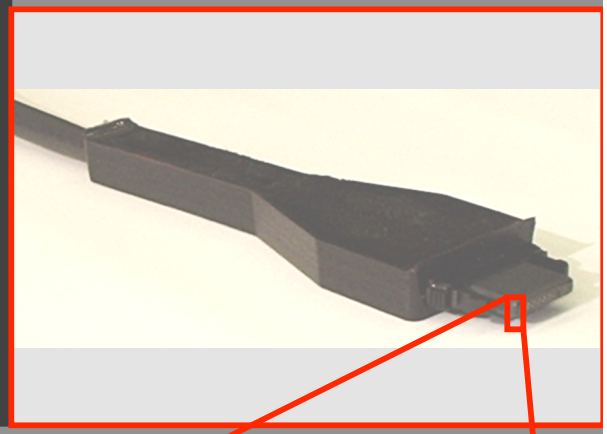
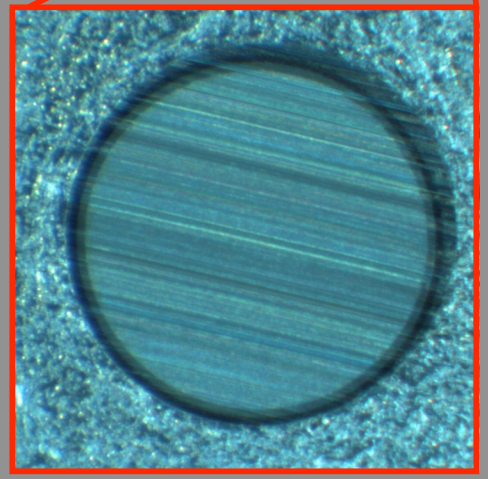
MINERνA: R&D / prototyping / expected performance



Fiber/connector light attenuation test

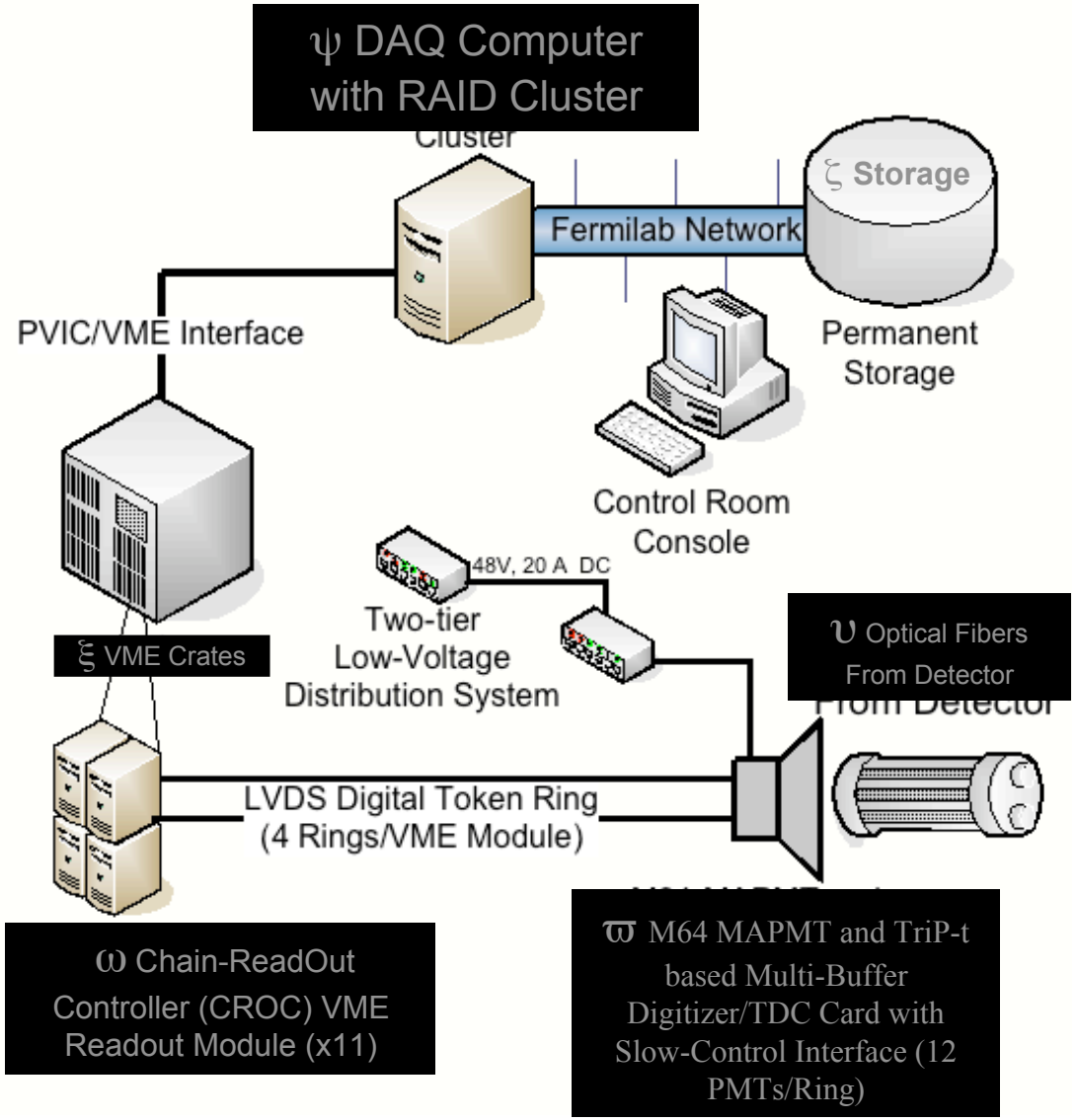




polished fiber in connector

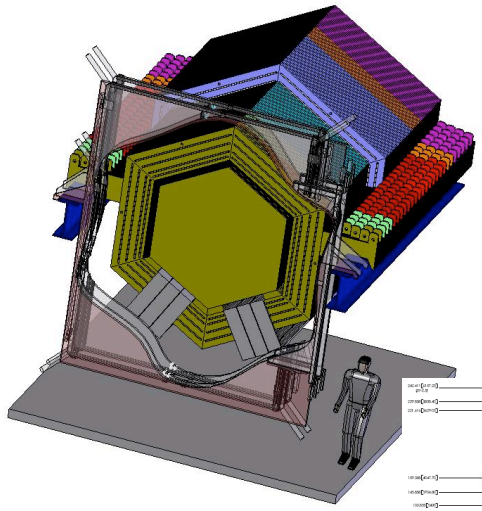
Electronics

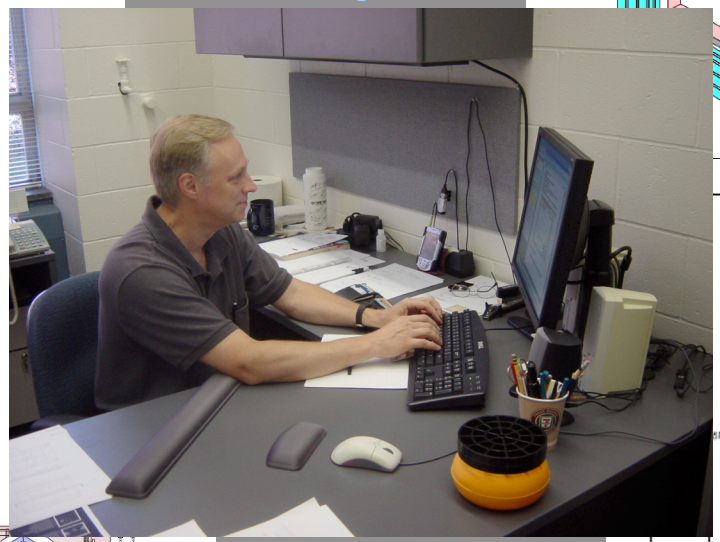
- Front-end Electronics
  - One board per PMT
  - ~1 MByte/spill
  - Digitization via TriP-t Chips, taking advantage of DØ design work



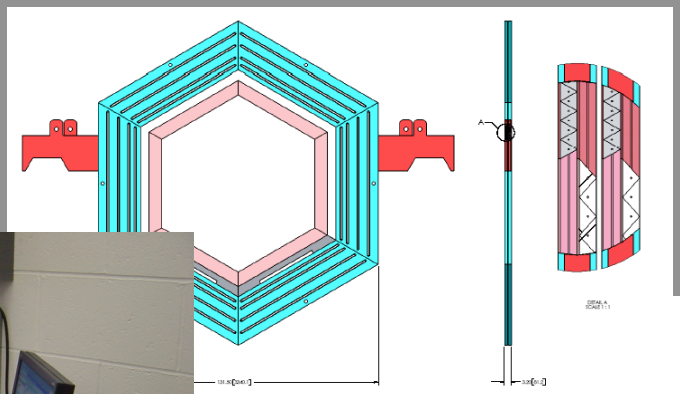
MINERνA: R&D / prototyping

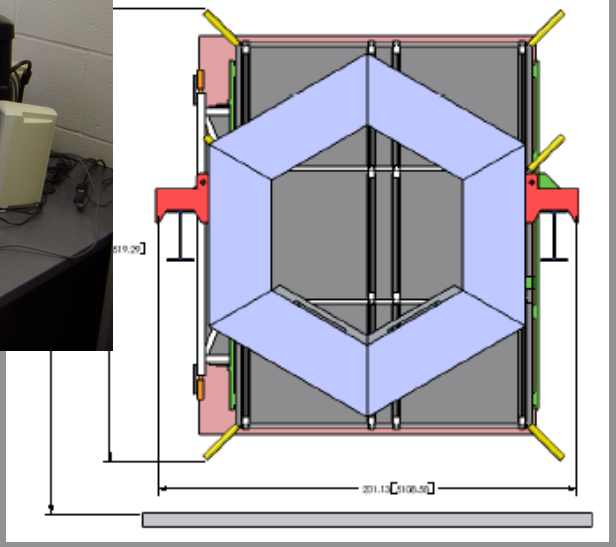
Detailed design, now down to fine-tuning

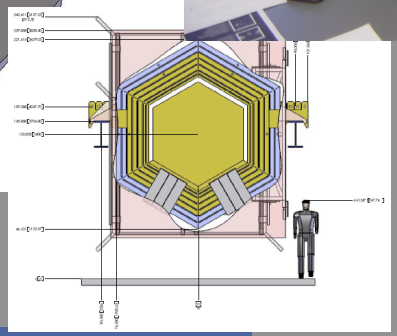




Robert Flight





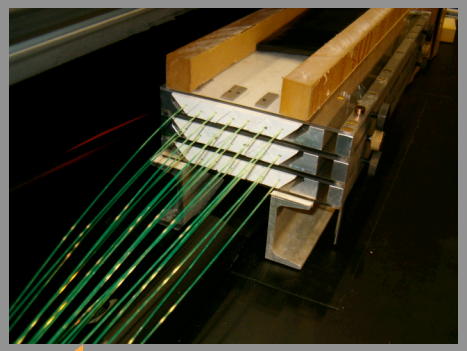


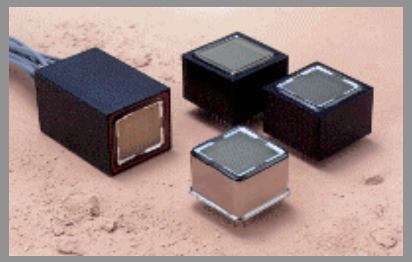
MINERvA Detector

Detector Channel Count:

- **31,000 channels**
  - 80% in inner hexagon
  - 20% in Outer detector
- **503 M-64 PMTs** (64 channels)
- **128 pieces of scintillator per Inner Detector plane**

Active elements are triangular bars of extruded scintillator with embedded 1.2 mm WLS fibers



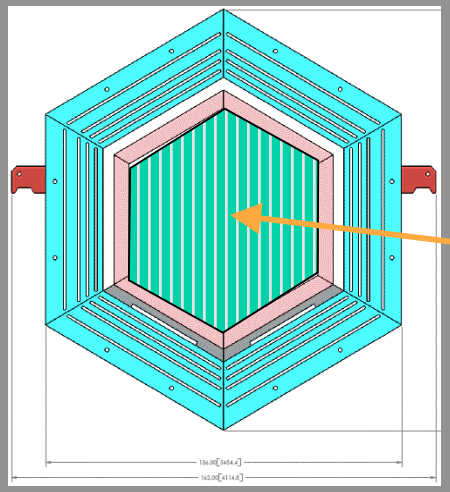


Readout- Hamamatsu M64

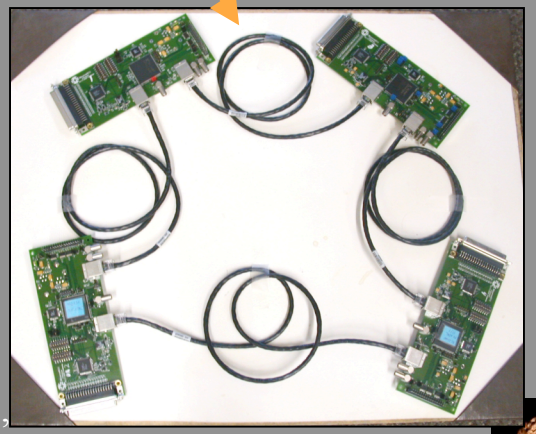
+

FE Readout Based on TriP-t ASIC and LVDS chain

ADC (triple range) plus few ns resolution timing



Inner detector is totally active scintillator strip detector. Alternating planes rotated by 60 degrees to make 3 views (XUXV)



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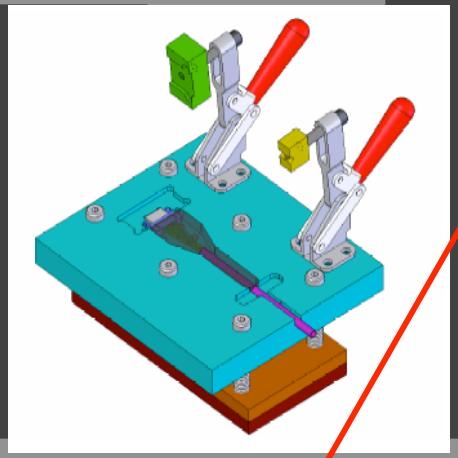
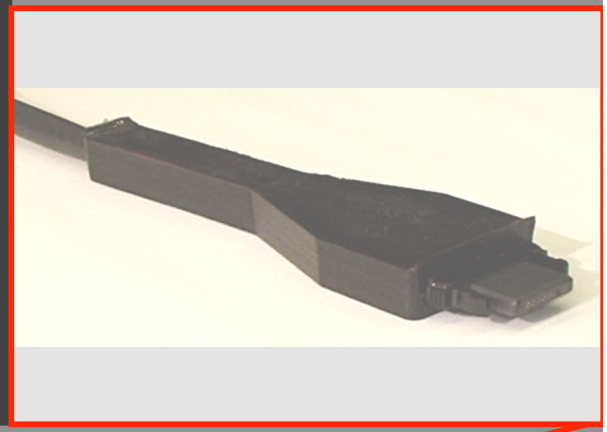
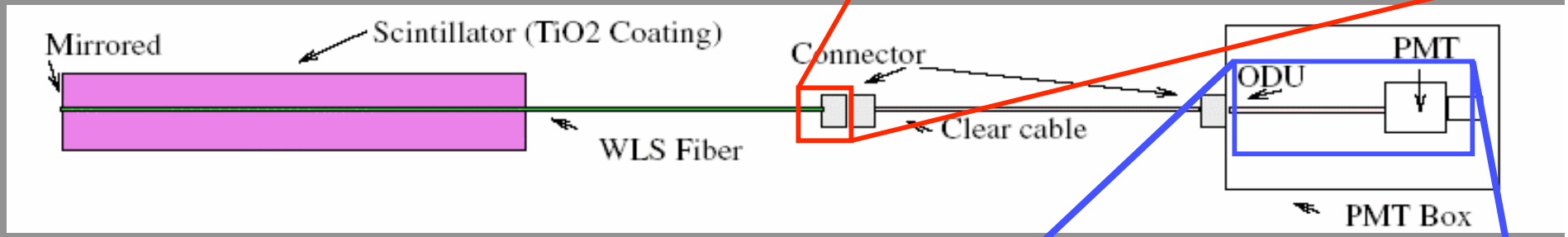
MINERvA: R&D / prototyping

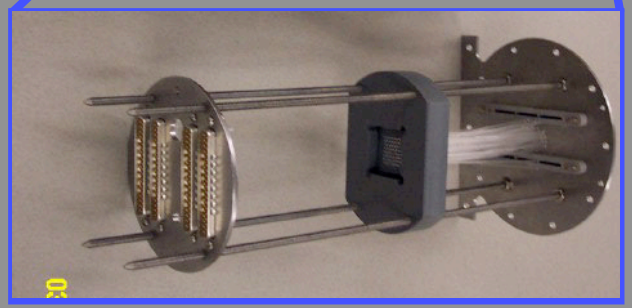
Tony Mann and crew





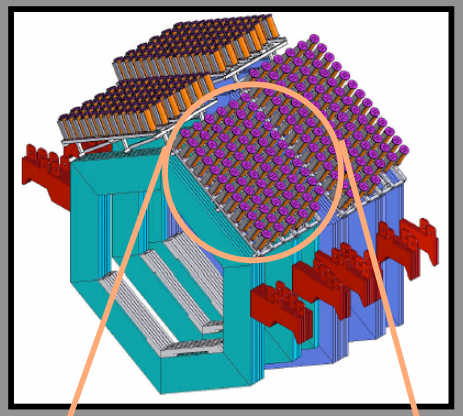


Optical path:
fibers/cables/connectors/PMT

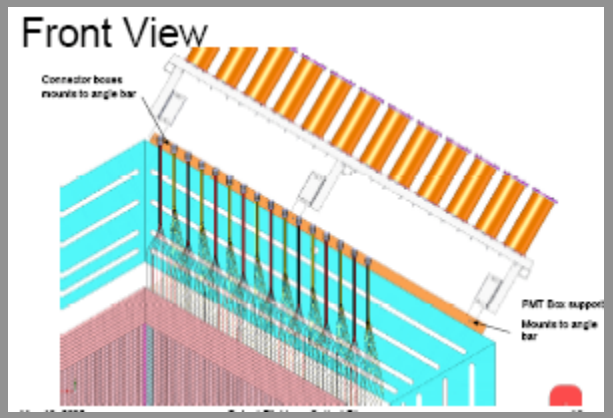


MINERνA: R&D / prototyping

Fiber routing and mechanical prototypes of layers



prototype PMT rack

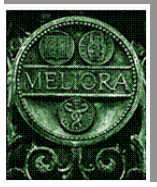


Full-size prototype

prototype module (layer substructure)

Quarter-size prototype

Bob Bradford
Jaewon Park
Zack Desantis



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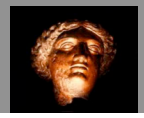


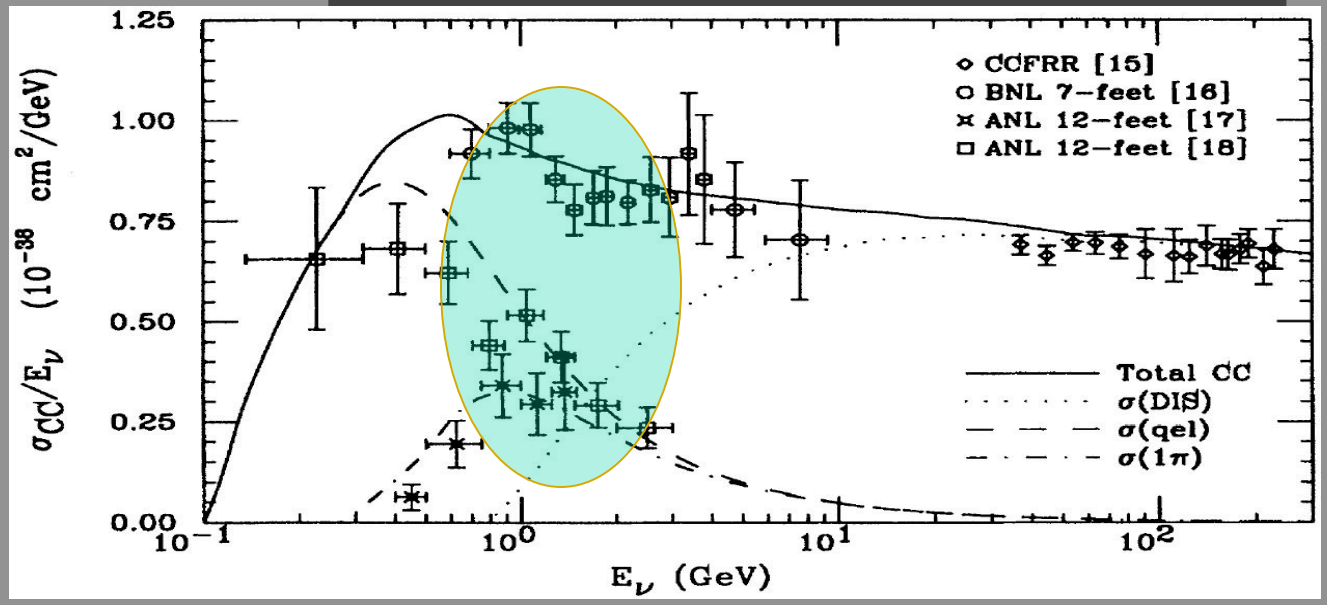
Motivation for MINERνA

Entering a period of precision neutrino oscillation measurements …

Got E_ν??

- Precision understanding of low energy (Few GeV) neutrino cross sections
- Models
- Nuclear effects
- Final state details

Lipari, Lusignoli and Sartogo, PRL 74, 4384 (1995)



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